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Effect of vermicompost on growth, quality and economic return of garlic (*Allium sativum L.*) at Haramaya District, Eastern Ethiopia

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Garlic (*Allium sativum* L.) is an important vegetable crop in Ethiopia. The yield of the crop is often constrained by low and unbalanced nutrient supply in the soil. This study was undertaken to assess effect of vermicompost (VC) on growth, quality and economic return of garlic variety Chelenko I during 2016 main rainy season in Haramaya University main campus, Ethiopia. The treatment consisted of four levels of vermicompost (0, 2.5, 5 and 7.5 tons ha^{-1}) laid out in a randomized complete block design in three replication. Data were collected and analyzed on days to emergency, plant growth, quality, and economic return of garlic. Results revealed early emergency (8.07 days) with application of 7.5 tons ha^{-1} of vermicompost while late emergency (10.13 days) was at nil application of vermicompost. Significant (P<0.05) maximum leaf area (37.05 cm^2), leaf area index (1.36) and biomass (61.54 g) were recorded with application of 7.5 tons ha^{-1}. Besides to this, maximum total dry matter (32.71%) and total soluble solid (12.72 Brix°) were also recorded at the rate of 7.5 tons ha^{-1}. Due to application of 7.5 tons ha^{-1} fertilizer, the economic analysis showed the highest net benefit cost of 431,188 ETB ha^{-1} and marginal rate of return (168.87%) with incurred highest total variable cost of 79,350 ETB ha^{-1}. Thus, it can be reasonably generalized that on short time basis, the application of high amounts of VC fertilizers can result in higher economic return than the low dose of VC fertilizer. Therefore, it can be concluded that, the maximum growth and quality and economic return of garlic was obtained with application of 7.5 tons of VC ha^{-1} fertilizer as it gave the highest net benefit cost. However, since the experiment was done only once and at one location, similar experiments should be carried out using additional higher rates of VC fertilizer over several seasons and locations to make a conclusive recommendation.

Key words: Chelenko I, economic return, marginal rate return, net benefit, total soluble solids.

INTRODUCTION

Garlic (*Allium sativum* L., 2n=16) belongs to the Alliaceae family, the same family as onions, shallots and leek (Allen, 2009; Hussena et al., 2014). According to Brewester (2008) cultivated garlic is a species of monocot, bulb- forming biennual grown as annual. Its relatives include onions and shallots (*Allium cepa*) and leeks (*Allium ampeloprasum*). It is the second most widely used cultivated *Allium* after onion (Rubatzky and

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Yamaguchi, 1997; Hamma et al., 2013; Hassan, 2015). Garlic is primarily grown for its cloves, which are used mostly as food flavoring condiments due to groups of sulphur containing compounds, allin and allicin (Messiaen and Rouamba, 2004). It is widely cultivated spice crops used for food and medicinal purposes (Diriba et al., 2013). Green tops are eaten fresh and cooked especially in tropical areas and consumption of immature bulbs for salad use is also popular (Block, 2010).

In Ethiopia, the acreage of garlic cultivation decreased from 16411.19 ha in 2013/2014 to 9257.71 ha in 2014/2015 with a total production of about 1590935.75 and 934868.73 tons of bulbs with the productivity of 9.7 and 10.1 tons ha^{-1}, respectively. Though acreage of garlic, production and productivity were not indicated in Eastern Hararghe, about 27190 farmers produced garlic (CSA, 2015). The yield of recently released garlic variety, Chelenko I, gave 9.3 t ha^{-1} on research field was appreciated and selected for Eastern and Western Hararghe (Tewdros et al., 2014), though its productivity is less than national productivity.

The economic importance of the garlic crop has increased considerably in the entire world in recent years. Despite its importance, growing garlic is faced by various problems during growth period (Shafeek et al., 2015). In Ethiopia, major production constraints include lack of proper planting material particularly shortage of improved varieties, imbalanced fertilizer use, lack of irrigation facilities, lack of proper disease and insect pest management and other agronomic practices, lower soil fertility status in many soil types, and lack of proper marketing facilities (Getachew and Asfaw, 2000; Mohamed et al., 2014) all which considerably reduce yield. Among the primary macronutrients, N, P and K are the most commonly reported deficient plant nutrients in most Ethiopian soils (Berga et al., 1994; Yohannes, 1994). Sub-optimal levels of these nutrients in the soil adversely affect the yield, quality and storability of bulbs of garlic crops (Gubb and Tavis, 2002).

Garlic is heavy feeder and most of the *Allium* species have low nutrient extraction capacity than most crop plants because of their shallow and un-branched root system. Therefore, adequate nutrient supply is essential for healthy crop growth and for attaining higher yield in sustainable way (Jones et al., 2011; Cantwell et al., 2006). Optimum application of fertilizers to garlic crop is important for improving growth, yield and marketable bulb proportions as well as bulb quality (Diriba et al., 2013). Organic inputs are often proposed as alternatives to mineral fertilizers. Organic fertilizers like wood ash, poultry manure, and fermented slurry were reported to produce garlic having low moisture content, high pungency, and higher mineral composition (Babatunde et al., 2009). However, the traditional organic inputs such as crop residues, and animal manures cannot meet crop nutrient demand over large areas because of the limited quantities available, the low nutrient content of the materials, and the high labour demands for processing and application (Pratap et al., 2011). Therefore, the application of bio-fertilizers like VC has been recognized as an effective means for improving soil aggregation, structure and fertility, increasing microbial diversity and populations, improving the moisture-holding capacity of soils, increasing the soil Cation Exchange Capacity (CEC) and increasing crop yields (Hargreaves et al., 2008). They also reported that municipal soil waste compost can also reduce the volume of the waste, kill pathogens that may be present, decrease germination of weeds in agricultural fields, and destroy malodorous compounds.

Vermicompost (VC) is slow releasing organic manure which has most of the macro as well as micronutrients in chelated form and fulfills the nutrient requirement of plants for longer period. Vermicompost helps in reducing C: N ratio, increased humic acid content and provide nutrient in the readily available form to the plants such as nitrate, available phosphorus, soluble potassium, calcium and magnesium (Talashilkar et al., 1999). Besides, Alemu et al. (2014) reported that increased levels of VC from 0 to 5 t VC ha^{-1} increased soil fertility with increased economic return.

Application of VC is crucial to increase productivity of plants with reduced pollution of environment. Possibilities to enhance garlic productivity in the Eastern Hararghe, Ethiopia have been the domain of investigation of recent years though nationally expected yield is not achieved yet. Farmers around the study area, Haramaya produce the local varieties of garlic crop in homesteads. However, recently Haramaya University has released new garlic variety Chelenko I (Tewdros et al., 2014). Varieties may also differ in their response to source and rate of applied fertilizers (Zhou et al., 2005). Moreover, no work has been done on effect of VC on the performance of garlic in the area. Therefore, the study was initiated to assess the effect of VC on growth, quality and economic return of garlic.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Haramaya University main campus during the main crop growing season (August-December) of 2016. Its altitude is about 2006 m above sea level, 9°24''N latitude and 42°03''E longitude. The site has a bimodal rainfall and is representative of a sub-humid and mid-altitude agro-climatic zone. The short rainy season extends from March to April whereas the long rainy season extends from June to October. The mean annual rainfall and temperature are 790 mm and 17°C, respectively (Belay et al., 1998; Simret et al., 2014). The minimum and maximum temperatures are 3.8 and 25°C, respectively (Tekalign and Hammes, 2005). However, in this crop growing season, from May to December 2016, the total annual rainfall was 566.1 mm, mean maximum and minimum temperature were 24.04 and 13.14°C, respectively. The soil of the experimental site is a well-drained deep alluvial (Tamire, 1975) with sandy loam texture

Table 1. Physical and chemical properties of the soil of the experimental site at Haramaya, Eastern Ethiopia.

Soil property	Value	Rating	Reference
Sand (%)	61	-	-
Clay (%)	23	-	-
Silt (%)	16	-	-
Textural class	Sandy clay loam	-	Moodie et al. (1954) and Rowell (1994)
pH 1: 2.5 (H_2O)	7.4	Slightly alkaline	Jones (2003)
OC	1.48	Low	Tekalign (1991)
OM (%)	2.55	Low	Tekalign (1991)
Total N (%)	0.18	Medium or moderate	Berhanu (1980) and Hazelton and Murphy (2007)
Available P (mg kg^{-1})	5.58	Low	Hazelton and Murphy (2007)
Exchangeable K(Cmolc kg^{-1})	0.32	Medium	Hazelton and Murphy (2007)
CEC (cmol (+) kg^{-1})	18.61	Medium	Landon (1991)

OC, Organic carbon; OM, organic matter; CEC, cation exchange capacity.

(Simret et al., 2014).

Experimental materials

Garlic variety Chelenko I was used which was released in 2014 for mid to high altitude garlic growing areas of eastern and western Hararghe Zones by Haramaya University. Its yield is stable over seasons and locations in the eastern highlands of the country. It is well adapted with productivity of 9.3 t ha^{-1} and moderately susceptible to garlic rust in Eastern Ethiopia. It takes about 132 days to mature (Tewodros et al., 2014).

Treatments and experimental design

The treatments consisted of four rates of vermicompost (VC: 0, 2.5, 5.0 and 7.5 t ha^{-1}). The experiment was laid out in randomized complete block design with three replications.

Experimental procedures and crop management

Experimental field was ploughed by a tractor. The plots were leveled and the ridges of about 20 cm height were prepared. The gross plot size was 2.0 m × 1.5 m. In between blocks and plots, 0.75 and 0.5 m space was left, respectively. Vermicompost (VC) was applied about two weeks before planting to randomly assigned treatments to each plot. Healthy and uniform medium-sized cloves of 1.5 to 2.50 g (Fikreyohannes et al., 2008), were selected and planting was done on 11 August 2016 at the depth of 3 to 4 cm. The cloves were planted on the ridge at a spacing of 30 cm between rows and 10 cm between plants. Thus, there were five rows in each plot and 20 plants in a row. The outer most one row on each side of a plot and 20 cm on both ends of each row were considered as border. Thus, the net plot size was 0.9 m × 1.8 m. Mancozeb was applied at the rate of 3.5 kg ha^{-1} mixing with water in a ratio of 2 gm L^{-1} (Anonymous, n.d.). This was done after a month from planting when fungus (garlic rust) symptom appeared on garlic leaf. All other recommended cultural practices to produce the crop such as weeding, harrowing and watering were applied uniformly and regularly to the entire plots throughout the experiment time as per the recommendation of Debre Zeit Agricultural Research Centre (Getachew and Asfaw, 2000). When 70% of the plants showed neck fall (Getachew and Asfaw, 2000; EARO, 2004), harvesting of bulbs was done on starting from 16 December 2016.

Vermicompost and soil sample nutrient analysis

Vermicompost sample, made from *Lantana camara, Partinium hystrophorous* and farmyard manure, was analyzed before applying to the soil. Samples were taken randomly from the entire bag. It was broken into small crumbs and prepared for determining chemical properties. The sample was air-dried and sieved through a 2 mm sieve. Its EC and pH were determined from the filtered suspension of 1:2.5 soils to water ratio using a glass electrode attached to a digital EC meter and pH meter (Jones, 2003). Sample was analyzed for electrical conductivity (EC), total N, available P, exchangeable K, organic matter and organic carbon. Total N was determined using the Kjeldhal method (Jackson, 1958). Available P was determined by extraction with 0.5 M sodium bicarbonate ($NaHCO_3$) according to the methods of Olsen et al. (1954). Exchangeable potassium was determined with a flame photometer after extraction with 0.5 ammonium-acetate according to Hesse (1971). Organic carbon of soil was determined by the Walkley-Black method (1934).

In similar way, soil sampling was done before planting. The samples were taken randomly using an auger in a zigzag pattern from the entire experimental field. Before planting, ten soil samples were taken from the top soil layer to a depth of 20 cm and composited in a bucket to represent the site. The soil was broken into small crumbs and thoroughly mixed. From this mixture, a composite sample weighing 1 kg was filled into a plastic bag. The chemical content of the soil was determined using similar procedures used for the VC as it was developed for the soil. Soil texture was determined by Bouyocous hydrometer method (Moodie et al., 1954).

Data collection and measurements

Days of emergency

Days of emergency was determined by counting when about 50% of the plants emerged.

Growth parameter

Leaf area was determined from 10 randomly taken plants from the central rows using the formula:

LA = LL × LW × 0.733

where LA = mean leaf area of the plant, LL = leaf length, LW = maximum leaf width, and 0.733 = conversion factor for leaf area.

Leaf area index was determined using the value of the leaf area divided by the area of the land occupied by the plants according to Watson (1958) using the following formula:

Leaf area index (LAI) = Lam × N/A

LA = LL × LW × 0.733

where Lam = mean leaf area of the plant, LL = leaf length, LW = maximum leaf width, 0.733 = conversion factor for leaf area, A=the area (cm^2) occupied by one plant in the cropping area, and N= number of leaves on the plant

Total fresh biomass yield (g/plant) was determined by taking the total weight of five randomly sampled plants from the four central rows of fresh bulbs, leaves, stems and roots using a sensitive balance.

Quality parameters

Total soluble solid: This was measured by taking 100 g juice and diluting it in 50% of distilled water, and then refractometer was used for evaluation.

Total dry matter (%): The average dry matter weight (g) of total biomass after curing was measured by drying 10 randomly sampled plants in an oven with a forced hot air circulation at 70°C until a constant weight was obtained. The percent of bulb dry matter calculated by taking the ratio of the dry weight to the fresh weight of the sampled plants and multiplying it by 100.

% BDM = (Weight of total dry matter / Total fresh weight) × 100

Data analysis

Data collected were subjected to analysis of variance (ANOVA) using SAS software version 9.0 and the means separated by using Turkey's Method at 0.05 level of significant if treatments were found significant.

Partial economic return analysis

The partial budget analysis as described by CIMMYT (1988) was done to determine the economic feasibility of the garlic production using the prevailing market prices for inputs at planting and for the outputs at the time of crop harvest. It was calculated by taking into account the additional input and labor cost involved due to additional input and the gross benefits obtained from garlic production. Average yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could obtain under their management practices as described by CIMMYT (1988). The field price of garlic was calculated as (sale price minus the costs of harvesting, cleaning, bagging and transportation). The net benefit was calculated as the difference between the gross field benefit (ETB ha^{-1}) and the total variable costs (ETB ha^{-1}).

Marginal rate of return (MRR %)

MRR was calculated by dividing change in net benefit or gross benefit by change in cost which was the measure of increasing in return by increasing input. This means by subtracting gross benefit of nil from gross benefit of each treatment and divided by the total variable cost of each treatment and multiplying each value by 100%.

$$\text{Marginal rate of return (\%)} = \frac{\text{Change in net benefit}}{\text{change in total cost}} \times 100$$

RESULTS AND DISCUSSION

Physical and chemical properties of the soil

The result of laboratory analysis of selected physical and chemical properties of soils of the experimental area is shown in Table 1. The textural class of the soil was sandy clay loam based on the soil textural triangle of the International Society of Soil Science system (Moodie et al., 1954; Rowell, 1994). The pH of the experimental soil was 7.4 which is slighty alkaline on the basis of pH limit (7.4 to 7.8) described by Jones (2003). The pH is in the range of 6.5 to 7.5 favorable for garlic production (Bachmann, 2001).

The organic matter (OM) of the experimental soil was 2.55%. According to Tekalign (1991), OM ranging from 0.86 to 2.59 is low, hence the soil might respond to the applied VC, as its organic matter content was low.

As per the rating (0.12 to 0.25%) described by Berhanu (1980), the total N content of the soil (0.18%) was medium. This value showed that the crop might respond to the applied VC (Table 1) due to increased soil fertility with application of fertilizers. According to the rating (5 to 9 mg P kg^{-1}) suggested by Cottenie (1980), the available P of the soil was low (Table 1). This may be because of low percent of OM content of the soil (Table 1) which is also in agreement with the suggestion of Clark et al. (1998) who indicated that soil OM influences P availability to crops directly by contributing to P pool. However, Toung et al. (2000) reported that P response is likely in soils that have less than 20 mg kg^{-1} extractable P. The cation exchange capacity (CEC) of the experimental soil was 18.61 (cmol (+) kg^{-1}). This value was medium according to the rating (15 to 25) suggested by Landon (1991). This indicated that the soil of the experimental site might respond to the different rates of VC. Hazelton and Murphy (2007) categorized exchangeable soil potassium contents of 0.3 to 0.7 Cmolc kg as medium. In accordance with this category, the exchangeable soil potassium content of the experimental soil is in medium category. This indicates external application of mineral and/or organic fertilizers containing potassium is important for enhancing the fertility of the crop and yield of the crop.

Vermicompost chemical properties

Chemical analysis of VC is indicated in Table 2. Its component was with EC: 8.83 msm^{-1}, pH: 7.25, total N was 0.56%, 25.82 ppm of available P, exchangeable K

Table 2. Chemical properties of vermicompost.

No. of VC	Chemical properties						
	Total N (%)	Available P (mg kg^{-1})	Exchangeable K [Cmol(+)kg^{-1}	OM (%)	OC (%)	pH	EC (msm^{-1})
Value	0.56	25.82	23.69	15.39	8.92	7.25	8.83
Rating	Very high	Moderate	Very high	Very high	Very high	Nuetral	Very high

OC, Organic carbon; OM, organic matter; VC, vermicompost; EC, electric conductivity.
Source: Hazelton and Murphy (2007).

Table 3. Effects of application of vermicompost on days to emergency, fresh biomass, total dry matter, leaf area , leaf area index, and total soluble solid of garlic.

Factor	Treatment	Days to emergency (days)	FB (g)	Total dry matter (%)	Leaf area (cm^2)	LAI	TSS (Brix°)
VC (t ha^{-1})	0	10.13^{c}	56.19^{c}	27.01^{c}	30.32^{c}	0.87^{c}	11.92^{d}
	2.5	9.00^{b}	59.05^{b}	29.18^{b}	32.37^{bc}	1.03^{b}	12.27^{c}
	5	8.67^{b}	60.08^{ab}	31.37^{a}	33.99^{b}	1.12^{b}	12.45^{b}
	7.5	8.07^{a}	61.54^{a}	32.71^{a}	37.05^{a}	1.36^{a}	12.72^{a}
LSD (0.05)		0.50	2.29	1.50	2.48	0.09	0.08
CV %		5.76	3.96	5.09	7.57	8.79	0.67

was 23.69 Cmol(+)kg^{-1} VC, 15.39% of OM and OC was 8.92%. These VC increases soil fertility without polluting the soil, as well as the quantity and quality of crops. Moreover, beneficial effects of VC on plant growth under water deficit conditions may be due to better aeration to the plant roots, increasing amount of readily available water, induction of N, P and K exchange thereby resulting in better growth of the plants. Application of bio-fertilizers such as VC have been recognized as an effective means for improving soil aggregation, structure and fertility, increasing microbial diversity and populations, improving the moisture-holding capacity of soils, increasing the soil cation exchange capacity and increasing crop yields (Hargreaves et al., 2008).

Days to emergency

Vermicompost (VC) application significantly influenced days to emergence. With the increase in the rates of VC application, the number of days required by the garlic sprouts to emerge above the soil surface was decreased. This means that plants that were not treated with the VC emerged from the soil later than plants that were treated with the VC. Thus, increasing the rate of vermicompost from nil to 7.5 t ha^{-1} hastened the emergence of garlic sprouts from the soil by 20.35%. The hastened duration for emergence due to the increased application of the VC may be attributed to the influence of nutrients released from vermicompost on root initiation and development which might lead to early shoot emergence. Similarly, Atiye et al. (2000) found that seedlings emergence of tomato, cabbage, and radish was much faster in higher rates of vermicompost than in nil application. Juan et al. (2006) also observed that the use of vermicompost as a substrate produced an earlier shoot emergence and earlier start of bulbification. This corresponds to increase the total soluble carbohydrates and a subsequent modification in the non-structural carbohydrate distribution patterns, and hence a modification in the pattern of fructan (scorodose) metabolism. The author therefore concluded that scorodose accumulation is directly related to the harvest index and is shown as greater yield and bulb quality.

Growth parameters

Fresh biomass

Analysis of variance showed that application of VC had very highly significant effects (0.001) on fresh biomass. With increased VC from 0 to 7.5 t ha^{-1}, fresh biomass increased by 9.5% over control (Table 3). Earthworm castings (worm manure) are rich in microbial activity and plant growth regulators, and fortified with pest repellence attributes as well (Suparno et al., 2013) that increase total fresh biomass. An important feature of VC is that, during the processing of the various organic wastes by earthworms, many of the nutrients that it contains are changed to forms that are more readily taken by plants such as nitrate or ammonium nitrite, available phosphorous and soluble potassium, calcium and magnesium (Suthar and Singh, 2008). In line with this result, application of vermicompost significantly influenced fresh biomass yield (Alemu et al., 2016). The author also observed that fresh biomass yield increased by 4.71% as the vermicompost was increased from 0 to 5 t ha^{-1}.

Leaf area

Vermicompost (VC) fertilization significantly ($P<0.01$) affected the mean leaf area per plant of garlic. The highest mean leaf area per plant (37.05 cm^2) was achieved at 7.5 t VC ha^{-1} while the lowest was obtained from the unfertilized plots (Table 3). Therefore, increasing VC resulted in increased leaf area of garlic.

Leaf area index

Leaf area index was significantly affected by application of vermicompost ($P < 0.001$). Vermicompost supplement at a rate of 7.5 t ha^{-1} increased leaf area index of garlic by 56.32% compared to control (Table 3). The increase in leaf area index in response to increasing rate of vermicompost may be ascribed to the availability of optimum nutrients contained in manure that led to high leaf area index through facilitated vegetative growth. This result is in line with that of Mehdi et al. (2012) who reported that it significantly increased all the growth attributes such as plant height, stem diameter, number of leaves, and leaf area index in response to applied municipal solid waste and vermicompost under well-watered, moderate and severe stress conditions. Alemu et al. (2014) also reported increased leaf area index of garlic with increased rate of VC application.

Quality parameters

Total dry matter

Bulb dry matter percent was significantly influenced by vermicompost ($P < 0.001$). Garlic bulb dry matter percent was increased by 21.10% due to vermicompost application at 7.5 t ha^{-1} rate over the control (Table 3). This result is supported by Juan et al. (2006) who showed that vermicompost increased the bulb dry weight due to the accumulation of non-structural carbohydrates whose distribution patterns change, thus favouring the metabolism of fructan precursors and accumulating as scorodose. The author further explained that such reserve substance (scorodose) accumulation in the vermicompost treatment represented by scorodose polysaccharide, occurs for a longer period due to the earlier start of bulbing. This response translates into a 2-fold increase of the bulbs dry weight, increased size and therefore, higher quality and yield at harvest. Similarly, Fenwik and Hanley (1985) reported that, in garlic, the fructan polysaccharide is the scorode which accounts for 53% of garlic dry matter. Alemu et al. (2014) also reported that the garlic bulb dry matter percent was increased by 8.13% due to vermicompost application at 5 t ha^{-1} rate over the control.

Total soluble solid

Total soluble solid was significantly influenced by vermicompost ($P < 0.001$). Application of 7.5 t VC ha^{-1} increased TSS by 6.7% compared to control (Table 3). It might be due to more accumulation of reserve substances in the bulbs. This result is supported by the findings of Alemu et al. (2014) who found a higher fruit density and more TSS in tomato due to application of vermicompost as compared to the treatment to which vermicompost was not applied. Alemu et al. (2014) also reported that application of 5 t VC ha^{-1} increased TSS by 11.04% compared to control.

Economic return analysis

As indicated in Table 4, economic analysis was done for main effects as it shows significant effect on marketable bulb yields. The variable cost considered was VC fertilizer cost with its application cost as well as extended days for gardener (60 ETB per (day + night)) of each treatment over control was considered. Even though there is no variable cost (the costs of fertilizer requirements and application were not included) in absolute control or nil application of VC fertilizer, the lowest benefit cost was obtained. On the other hand, treatment with application of VC is economically sound full than over control. Alemu et al. (2016) pointed out that the highest net benefit with the highest total variable cost and the lowest was with no variable cost or the area which was with nil application of VC for garlic crop. The study undertaken on two soils types by Diriba et al. (2015) also showed that the growth, yield and economic potential of garlic were increased in response to fertilizer application.

Maximum net benefit (364250 ETB ha^{-1}) was obtained with application of 7.5 t VC ha^{-1} fertilizer while the least net benefit cost (309600 ETB ha^{-1}) was obtained with unfertilized. Verma et al. (2013) also reported that combined application of 5.0 t VC ha^{-1} and 60 kg S ha^{-1} was superior with respect to net returns of garlic. As to this finding, it is profitable to cultivate garlic with application of 7.5 t VC ha^{-1}. Alemu et al. (2016) also reported that net benefit of 163532 ETB ha^{-1} with application of 5 t VC ha^{-1}. Marginal rate of return percent

Table 4. Partial budget analysis of the economic performance of garlic under VC fertilization.

Factor	Treatments	Average yield (t ha^{-1})	Adjusted yield (t ha^{-1})	Gross benefit (ETB ha^{-1})	Total variable cost (ETB ha^{-1})	Net benefit (ETB ha^{-1})	%MRR
	0	8.6	7.74	309600	0	309600	-
VC	2.5	10.1	9.09	363600	26450	337150	204.36
(t ha^{-1})	5	11.34	10.21	408400	52900	355500	186.77
	7.5	12.32	11.09	443600	79350	364250	168.87

Price of vermicompost = 10.00 ETB kg^{-1} + application cost of 1390.00 ETB per 2.5 t ha^{-1} or 2780.00 ETB per 5 t ha^{-1} + 4170.00 ETB per 7.5 t ha^{-1}. Garlic selling price = 40.00 ETB kg^{-1}.
Source: Garlic selling price at Haramaya District (2017).

was reduced with increased rate of VC. Maximum marginal rate of return percent (204.36%) was obtained with application of 2.5 t VC ha^{-1} while the least (168.87%) was recorded with application of maximum levels of VC (7.5 t ha^{-1}). This was due to highly increased variable cost with increased rate of VC.

Conclusion

The analysis of variance indicated that effect of VC show significant effects on days to emergency, leaf area, leaf area index, fresh biomass, total dry matter percent and bulb quality. The highest net benefit was recorded with application of the highest rate of VC fertilizer (7.5 t ha^{-1}) while the highest marginal rate of return was obtained with application of 2.5 t VC ha^{-1} fertilizer application. The early emergency (8.07 days) was recorded with application of maximum rate of VC (7.5 t ha^{-1}) while late emergency (10.13 days) was with nil application of VC.

Growth parameters such as leaf area, leaf area index and fresh biomass are significantly influenced by the applied VC fertilizers. Maximum leaf area (37.05 cm^2) was recorded with application of maximum rate of VC (7.5 t ha^{-1}) fertilizer. The highest leaf area index (1.36) and fresh biomass (61.54 g) were recorded from 7.5 t VC ha^{-1} application. Total dry matter and soluble solid traits showed significant differences in response to the application of VC fertilizer. Maximum total dry matter (32.71%) and total soluble solid (12.72 Brix°) were recorded at the rate of 7.5 t VC ha^{-1}.

The economic analysis showed the highest net benefit cost of 431188 ETB ha^{-1} with incurred highest total variable cost of 79350 ETB ha^{-1} with application of 7.5 t VC ha^{-1} fertilizer. The least net benefit cost of 309600 ETB ha^{-1} was obtained with nil application of VC fertilizer. The highest marginal rate of return (204.36%) with application of 2.5 t VC ha^{-1} and the least (168.87%) with application of 7.5 t VC ha^{-1} was recorded. Thus, it can be reasonably generalized that on short time basis, the application of high amounts of VC fertilizers can result in higher economic return than the low dose of VC fertilizer. However, the results of the experiment have revealed that growth, quality and economic return did not reach the optimum since they all significantly increased in response to the application of VC fertilizer. Therefore, there is a possibility that significantly more growth characters, quality and economic return of the garlic could have been obtained if the rates of the VC fertilizers had been increased. Therefore, from the results of this study, it can be concluded that, the maximum growth and quality and economic return of garlic was obtained with application of 7.5 t VC ha^{-1} fertilizer as it gave the highest net benefit cost. However, since the experiment was done only once and at one location, similar experiments should be carried out using additional higher rates of VC fertilizer over several seasons and locations to make a conclusive recommendation.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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